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CHARACTERISTICS OF CUTTING PARAMETERS AND THEIR EFFECT ON THE GLASS EDGE QUALITY

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The optimum parameters of glass cutting are studied and substantiated: the material and the sharpening angle of the glass-cutting roll, the load applied to the roll, the role of the propping liquid, and the effect of all these parameters on the glass edge quality.

There are different methods for glass cutting. The simplest and the most accessible is the mechanical method, which consists in inflicting a cutting line on the glass surface using a hard-alloy roll cutter, when a system of cracks (the median and two lateral cracks) [1] is formed beneath the cutter, and breaking the glass along this line.

If the cutting is performed appropriately, the resulting glass edge is free of defects, has a lustrous smooth end face and perpendicular surfaces. Otherwise, the edge and the end face have a number of defects. The criterion for evaluating the edge quality is the strength of glass in lateral bending. Such defects as chips, scars, and notches that are formed on the end surface impair the exterior appearance, but have virtually no effect on the glass strength, whereas defects of the upper surface (chips, notches) have a significant effect on the glass strength [2].

Figure 1 indicates that glass strength in lateral bending decreases depending on the types of defects arising in cutting. The strength was measured on an R-0.5 breaking machine according to the method described in [2]. As the consequence of studying various defects, it is found that similar defects result from cutting “cold” (20 – 100°C) and “hot” (610 – 665°C) glasses.

The defects can arise both in inflicting a cutting line and in breaking glass along this line. The strength of the cut edge can be enhanced using a special treatment. Thus, mechanical treatment regardless of its type improves the glass strength by approximately 30%, however, it is impossible to accomplish the same strength as in a defect-free (smooth) edge. Consequently, the less defects the glass edge has after cutting, the higher the glass strength in lateral bending. It is possible to obtain a high-quality edge by following certain parameters of cutting: the characteristics of the roll cutter (material, size, sharpening angle), the pressure (load) of the roll on the glass in inflicting the cutting line, the presence of propping liquid, the speed of cutting. These parameters are determined by the type of cutting (manual or mechanized cutting) and the glass thickness. There are optimum parameters for each glass thickness [3, 4].

Glass is cut with hard materials. Diamond is good for this purpose, but the position of the cutting face of the diamond with respect to the glass surface is very significant. Failing to maintain a particular angle, the median crack can deviate from the vertical direction, and in this case the glass fracture will not coincide with the cutting line. That is why only skilled cutters use a diamond in their work. The most common instrument is a glass-cutting roll, although the glass edge quality in this case is not as good.

Due to the round shape of the roll, the median crack is virtually always vertically directed. The glass-cutting rolls are made of hard alloys. The alloy typically used in domestic industry is VK-3 (tungsten – cobalt) both for manual and

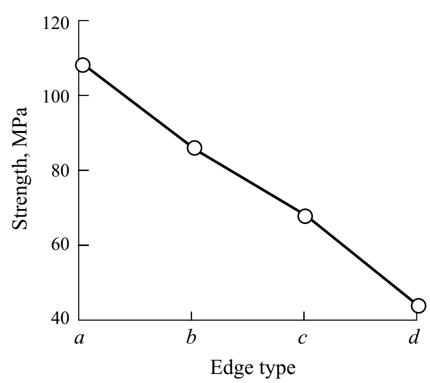

Fig. 1. Lateral bending strength of glass depending on the types of edge defects: *a*) defect-free edge, edges with defects more than 0.75 mm; *b*) notches not transformed into cracks; *c*) notches transformed into cracks; *d*) chips.

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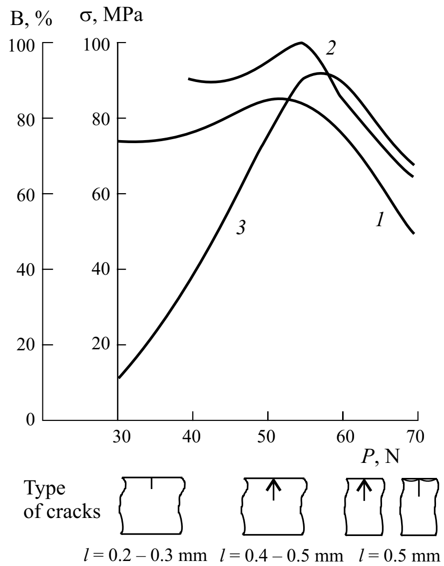

Fig. 2. Lateral bending strength σ and yield Y of acceptable sheets versus the load *P* applied to the roll: *1* and *2*) strength for roll sharpening angles 130 and 135°; *3*) yield of acceptable sheets (%).

machine cutting. These rolls are not very durable and soon become dull and have to be resharpened. Along with domestic roll cutters, imported rolls are used as well. The resistance of the most durable imported rolls made of high-quality precision-treated alloys exceeds many times the resistance of domestic roll cutters.

An example can be given of the effect of the roll material on the cutting quality. Thus, in the first quarter of 1999, two rolls made by Silberschnitt company (Germany) were tested on the longitudinal cutting beam of the ÉPKS-4000 line at the Saratov Institute of Glass. The rolls exhibited high resistance, namely, whereas a VK-3 roll has to be replaced 1 – 2 times a day, the specified rolls withstood 9 shifts, which led to an increased yield of acceptable glass sheets after cutting. The quality of the glass edge in that testing remained good for 8 shifts, and only then were some coarse defects observed at the edge.

A propping liquid is used in glass cutting and fulfills the following functions: penetrating into a crack, it acts as a wedge facilitating the crack growth and thus facilitates the fracture of glass along the inflicted cutting line.; it retards the lateral cracks reaching the surface and decreases the friction of the roll cutter against the glass. It is known that the breaking load in cutting glass using kerosene is 2 – 3 times lower than when cutting without liquid [3].

To investigate the effect of the propping liquid, of the sharpening angle, and of the load applied to the roll on the quality of cutting, several experiments were carried out (producing glass sheets in line with molding) to determine the lateral bending strength of glass and the depth of the median crack in cutting. The median crack depth was measured using an MBS microscope (× 56). For this purpose, we selected sheets with an inflicted cutting line (the breaking mechanism being switched off), then a band approximately 50 mm wide was cut out of such sheet along the entire cutting line (the cutting line was in the center of the band), and finally the band was divided on the lower surface into samples 20 – 25 mm wide.

It was established that the edges of sheet glass produced without a propping liquid had coarse appearance, the break did not always occur along the cutting line, and the lateral bending strength was about 48 MPa. The strength of glass with the edges produced using a liquid was about 84 MPa. The median crack depth was 0.25 mm without liquid and 0.50 mm using the liquid. When the liquid was used, lateral cracks were visible in the glass depth in addition to the median crack, whereas in the absence of liquid, chips were observed on the glass surface on both sides of the median crack, i.e., the lateral cracks have reached the surface and formed shavings. The study in [5] demonstrated the changes in the crack depth depending on the presence or absence of liquid. In inflicting a cutting line on glass, the uniform distribution of liquid along the whole cutting line is of special significance. This can be well seen on the ÉPKS-4000 production line (the lateral cutting beam): when a roll is not sufficiently moistened, it arrives to the end of the line quite dry. In such a case, a sort of “corner” is left after the glass fracture.

Correct selection of the roll sharpening angle and the load applied to the glass by the roll cutter in inflicting the cutting line are very important. The kind of cracks arising beneath a roll cutter and, accordingly, the glass edge quality depends on the relationship between the above parameters. The roll sharpening angle can be 110 – 165°, and each angle correlates with a certain load, when a minimum breaking effort is required, or a through crack is formed [3]. Much attention is paid to these parameters in foreign countries. Whereas domestic manufacturers produce only semi-finished roll cutters requiring additional sharpening, foreign manufacturers make roll cutters with various sharpening angles. Thus, the Silberschnitt company offers ready-made roll cutters with various sharpening angles (over 10 varieties) for cutting glass 1 – 25 mm thick.

Rolls with sharpening angles 110, 130, 135, 140, and 150° were tested in cutting glass 5 mm thick. In employing a roll cutter with sharpening angle 110°, the glass virtually never broke along the cutting line. This can be attributed to the fact that the emerging median crack had an insufficient depth (0.1 – 0.2 mm). A high-quality (strong) edge resulted from cutting employing a roll cutter with sharpening angle 130 – 135°. As the sharpening angle increased, the edge quality deteriorated, and the strength decreased by half, which was due to the formation of lateral cracks and their reaching the glass surface. The strongest (100 MPa) edge for the maximum yield of acceptable (whole) sheets was obtained employing a roll with the sharpening angle 135° (the sheets were considered whole, if they fractured along the entire cutting line). Silverschnitt recommends applying rolls with sharpening angle 135° for cutting glass 3 – 8 mm.

The determination of the dependence of glass cutting quality on the load applied to the roll revealed as well the existence of the optimum value (Fig. 2). The strongest edge with a maximum yield of acceptable sheets was obtained in using a roll with sharpening angle 135° and a load of 55 – 60 N applied to the roll. An increase or a decrease in the load by 10 N reduced the number of acceptable sheets by 30 – 50%, i.e., there exists a narrow interval of sharpening angle and load values, which ensures a strong edge and the maximum yield of acceptable sheets.

In studying the median crack, it was established that under low loads (30 – 40 N) the crack's depth (0.2 – 0.3 mm) is insufficient for the glass to break along the cutting line (the yield of acceptable sheets about 10%), although the strength of the broken sheets is high, since the edges are smooth. As the load increases (50 – 60 N), the depth of the median crack increases as well (0.4 – 0.5 mm), the lateral cracks emerge, and the glass breaks along the cutting line. The strength reaches 100 MPa, and on a further increase in the load (70 N), it decreases by half, in which case the median crack almost does not grow, whereas some of the lateral cracks reach the glass surface.

Thus, in order to accomplish high-quality glass cutting (including cutting on a production line), it is necessary to maintain the optimum cutting parameters. Otherwise, the glass sheets have poor-quality edges, which decreases lateral bending strength, mars the external appearance of glass articles, and finally, decreases the yield of acceptable sheets. The better the edge quality, the less time is needed for its treatment. Therefore, the considered parameters should be strictly monitored and controlled in glass cutting.

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